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Adoption and Use of Improved Maize by Small-Scale Farmers in Southeast Guatemala

Gustavo Saín and Julio Martínez*

* Gustavo Saín is Regional Economist for Central America and the Caribbean with CIMMYT. Julio Martínez is an economist with the Instituto de Ciencias y Tecnologías Agropecuarias (ICTA) de Guatemala. The views represented in this paper are those of the authors and do not represent the official views of CIMMYT.

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Contents

Abstract

This report is based on a study of the adoption and use of improved open-pollinated varieties and hybrids by small-scale farmers in the Department of Jutiapa, Guatemala. The majority of maize producers in Guatemala are small-scale subsistence farmers. Approximately 60% of the basic grains produced in the country are grown on farms that are too small to satisfy the basic nutritional needs of a typical family (5–6 persons). Increasing yields through the use of new technologies is seen as a critical step to ensuring adequate nutrition and increasing farmer income in the area. The study, conducted in June and July 1991, randomly surveyed 208 farmers in 18 municipalities of Jutiapa, apportioned according to the number of farms in each municipality. There was particular interest in assessing the impact of the Project of Generation and Transfer of Agricultural Technology and Seed Production (PROGETTAPS), which was launched in 1986 by the Instituto de Ciencia y Tecnología Agrícolas (ICTA) and the General Directorate of Agricultural Services (DIGESA) with the goal of increasing small-scale farmers access to improved seeds. Study findings reveal a complex pattern of seed use in Jutiapa. Although the farmers there use several types of local and improved maize seed, they seem to prefer and use the local variety known as Arriquin, as well as two improved materials: an open-pollinated variety (B-1) and a hybrid (H-5). The reported forms of acquisition and preferences indicate that most of the farmers use the same material from 1 to 3 sowing seasons. Yield gains and relative prices, two important factors determining the profitability of adoption of new varieties, are adequate. By changing from their local varieties to OPVs and hybrids, farmers most likely can expect yield increases ranging from 35% to 70%. The decision to use improved materials in part or all of the area cropped with maize is associated with a change in the maize cropping system. Results suggest that farmers that sow a plot of maize in monoculture tend to plant the entire area with improved seed, particularly with hybrids. Results also show that the size of the family, taken together with the cropping system, is an important factor influencing the probability of full adoption, particularly of hybrid materials. The findings indicate that the probability of using hybrid materials, either in part or all of a cropped area, increases with farm size. Importantly, results from the estimating model confirmed the trend observed at the aggregate level. PROGETTAPS had a significant impact on the adoption of OPVs in Jutiapa. Farmers that have experience with PROGETTAPS are more likely to adopt OPVs than those who do not have contact with it. Furthermore, the probability of adoption increases with the years of association farmers have had with the program.

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Gustavo Sain and Julio Martinez

Introduction

Maize consumption and production in Guatemala

The Republic of Guatemala is the largest producer of maize in Central America (producing 42% of the region's maize), with almost 800,000 hectares of land in maize and annual production of 1.4 million tons. The importance of the crop to the Guatemalan economy is demonstrated by the fact that maize production accounts for approximately 10% of the total value of the national agricultural production.

Total maize consumption in Guatemala has grown steadily during the past 36 years at an annual rate of 3.1%. Maize production grew at roughly the same rate as consumption between 1960 and 1987, but fell to 1.2% annually from 1988 to 1996 (Figure 1). Maize yield grew at an annual rate of 2.8% from 1960 to 1987, but stagnated from that year to the present (Figure 2). With cropped area growing at a modest annual rate of 0.4% over the entire period, the decline in the growth of maize production is clearly associated with changes in productivity. Table 1 summarizes the growth rates of maize consumption, production, and production components for 1960–1987 and 1988–1996. To keep pace with the growing demand for maize, production must grow at a higher rate; given the scarcity of good quality land, those increases must come from higher yields. Improved germplasm offers one of the most effective and cost efficient options for reversing the current decline and increasing maize yields (Heisey, Morris, and Byerlee 1998).

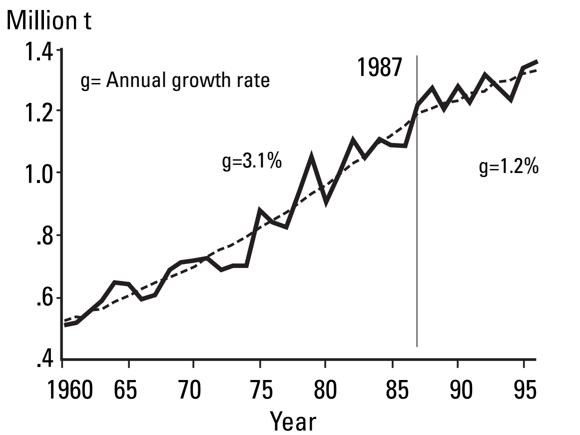

Figure 1. Maize production in Guatemala 1960–1996.

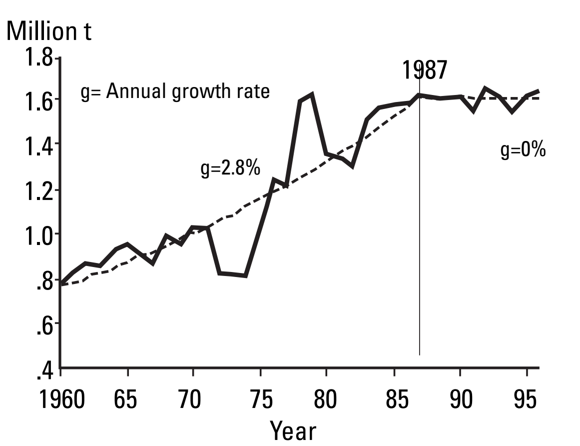

Figure 2. Maize yield in Guatemala, 1960–1996.

Table 1. Annual growth rates of maize consumption, production, harvested area, and maize yield in Guatemala, 1960–1996

	Annual growth rate (percent)			
Period	**Consumption**	**Production**	**Area**	**Yield**
1960–1987	3.01	3.08	0.46	2.78
1988–1996	3.01	1.24	0.46	0
Change	0	-1.84	0	-2.77

Source: Growth rates estimated as semilogarithmic regression. Data from USDA/ERS.

The majority of the maize producers in Guatemala are small-scale subsistence farmers. Approximately 60% of the country's basic grains are produced on small farms that cannot produce enough food to satisfy the basic nutritional needs of a typical family (5–6 persons). The numerical importance of these groups of farmers, their precarious nutritional situation, and their high rate of demographic growth demand a long-term effort aimed at improving their productivity and income (Herrera and Jiménez 1992). The incorporation of new technologies into existing maize production systems should help achieve these goals.

One strategy to effectively and rapidly increase yields is to promote more extensive use of improved maize varieties and hybrids by small-scale farmers. Although the availability of improved maize seed has steadily grown between 1977 and 1993, the supply has not sufficiently met demand, and access to this resource by small-scale farmers has been seriously limited. In 1993, 31% of the harvested maize area was sown with improved varieties (Lopez Pereira 1995); open pollinated varieties (OPVs) accounted for 19% of the total area while hybrids accounted for the remaining 12%. The principal users of the improved varieties, however, were medium- and large-scale farmers (Echeverría 1990). Although the percentage of area under OPVs is above the average for Central America (including México) and for Latin America as a whole, the percentage of area sown with hybrid materials is below the respective averages of both regions. Overall, the percentage of area sown with improved varieties is below the 40% reported for developing countries, excluding Argentina, Brazil, China, and South Africa (Heisey, Morris, and Byerlee 1998).

Maize seed production in Guatemala

Domestic production of improved seed in Guatemala started in 1961 with the establishment of the Department of Seed Control and Certification. In 1973, the Instituto de Ciencia y Tecnología Agrícolas (ICTA), a semiautonomous public agricultural research institution, was created, followed in 1975 by a specialized division of ICTA, the "Disciplina de Semillas." In 1977, an agreement between the Inter-American Development Bank (IDB) and ICTA was signed with the objective of developing the seed industry in Guatemala. Under this agreement, ICTA built a seed processing plant and started producing improved seed.

Table 2. Maize area cultivated in Central America and Mexico by type of seed used, 1993

	Maize area cultivated in 1993 (000 ha)		Percent of area sown to		
	Total	Under improved seed	Local varieties	Open pollinated varieties	Hybrids
Mexico	7,348	2,638	64	10	26
Costa Rica	24	5	81	12	7
El Salvador	321	111	65	1	34
Guatemala	650	200	69	19	12
Honduras	435	82	81	7	12
Nicaragua	192	19	90	7	3
Panama	79	79	0	38	62
C. America	1,701	496	71	12	17
C. America and Mexico	9,049	3,134	65	10	25

Source: López-Pereira (1995).

The birth and expansion of private sector seed production in the late 1970s and early 1980's was vitally important. In particular, the arrival of the private company Cristiani-Burkard from El Salvador in 1981 was a turning point in the development of the seed industry. During the mid-1970s, most improved seed was imported. With the development of the domestic seed industry, imports started a steady decline in the late 1970s, and domestic, primarily private sector, production, consistently grew (Figure 3).

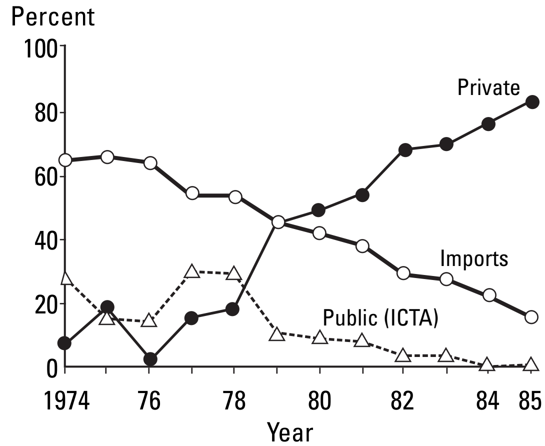

Figure 3. Improved seed availability by source of origin, Guatemala, 1974–1984.
Source: Veliz (1993).

The seed industry in Guatemala today is a public and private sector partnership. ICTA releases basic and foundation seed to private companies that produce certified commercial seed. ICTA also provides seed processing services. A small number of firms and individual producers comprise the private sector component of the industry, with Cristiani-Burkard capturing about 70% of the market. (Echeverria 1988; Veliz 1993). Between 1974 and 1985, public sector (ICTA) production of certified seeds of basic grains went from 28% to less than 1% of total production (Veliz 1993).

Although the availability of improved maize seed through conventional production systems grew between 1974 and 1985 (Table 2), the growth still did not meet the potential demand of small-scale farmers. To increase access by small-scale farmers to improved seeds, in 1986, ICTA and the General Directorate of Agricultural Services (DIGESA) launched the Project of Generation and Transfer of Agricultural Technology and Seed Production (PROGETTAPS).

The project initially included seven departments, but in 1989 eight more were added, for a total of 15 departments. The project emphasized the promotion and transfer of new genetically-improved materials, which were produced by ICTA and transferred by DIGESA. PROGETTAPS was jointly executed and took advantage of the linkage between research and extension agents, promoting a multiplier effect by incorporating farmers' participation in technology testing, adoption, integration, and transfer (Córdova, Queme, and Rosado 1992; Ortiz, Meneses, and Rosado 1989).

By 1987, the program was implementing technology transfer strategies and mechanisms at the local level that were aimed at generating seed production capacities in rural communities through the participation of small-scale farmers. It was thought that this approach would ensure that target group farmers would gain access to sufficient quantities of new improved materials (Córdova, Queme, and Rosado 1992). Although not included in the original project plan, the on-farm production of improved seeds evolved as a component of the project that made improved seed accessible to farmers who either could not afford to buy it or who lived in areas where it was not physically available (Ramiro Ortiz, personal communication).

Transfer plots created and supported by PROGETTAPS for diverse crops grew from 506 in 1986, to 4,630 in 1989 (Ortiz et al. 1991). Out of the recommended technological package for these plots, farmers generally only used the improved seed component. The intensive project activity during this period caused the on-farm production of certified maize seed through PROGETTAPS to grow at an annual rate of 22%, going from 26.1 t/yr in 1986, to 138 t/yr in 1992 (Table 3).

Table 3. Domestic production of certified maize seed in Guatemala, 1981–1992

	Production of certified seed by sector (t)	
Year	Conventional producers [1]	PROGETTAPS[2]
1977	318	
1978	260	
1979	632	
1980	1,100	
1981	969	
1982	1,135	
1983	1,791	
1984	2,814	
1985	2,343	
1986	1,865	26.1
1987	3,315	108.5
1988	1,609	84.0
1989	1,460	80.6
1990	2,197	92.4
1991	1,567	175.9
1992	1,654	137.8

Sources: [1] Years 1977–1980 from Echeverria (1988); years 1981–1992 from Veliz (1993)
[2] Years 1986–1990 from Valladares and Sain (1992); years 1991–1992 from Veliz (1993).

Objectives of this study

The general objective of this paper is to document the use of improved maize varieties in Jutiapa, Guatemala. In particular, the study aims to identify the main factors that influence small-scale farmers' decisions regarding the use or non-use of improved maize varieties and hybrids. Furthermore, the impact of the ICTA/DIGESA program on the diffusion of improved seed among small-scale farmers is explored. Finally, the study looks at the use preferences and intensity of use for different types of improved materials, and it identifies the diffusion pattern of improved OPVs and hybrids in the region (Figure 4).

The information found in this study can be usefully employed to refine strategies for the technology generation process and technology transfer (CIMMYT 1993). It can also help institutions improve systems and approaches for supplying improved seed to the poorest farmers.

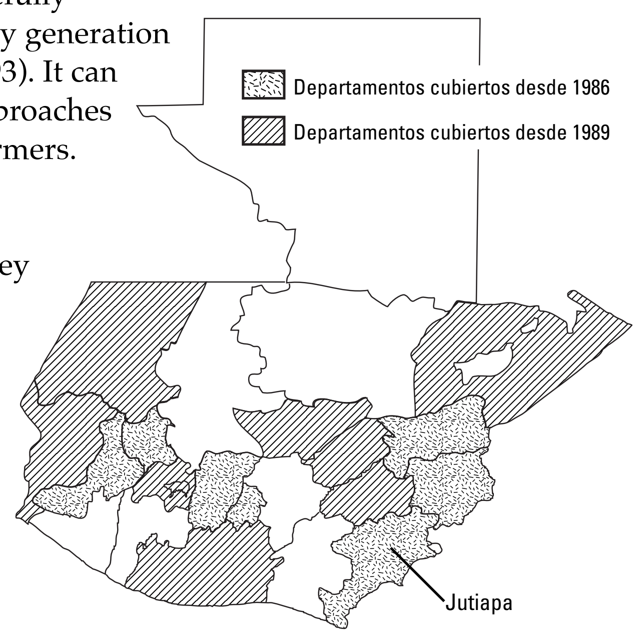

Figure 4. Geographical location of Jutiapa Department and PROGETTAPS.

Sources of data

The primary data originate from a formal survey conducted during June and July, 1991. The survey was coordinated by a technical team of the International Center of Tropical Agriculture (CIAT) and DIGESA, under the joint sponsorship of CIAT, the International Maize and Wheat Improvement Center (CIMMYT), and the Regional Maize Program (PRM). The survey was conducted by extension agents of DIGESA, who were previously trained to gather the information.

The sample size was 208 farmers, distributed in 18 municipalities of Jutiapa Department. This corresponds to approximately 2% of the total number of farms in the department. The number of farmers selected from each municipality was based on the proportionate number of farms in the municipality in relation to the of total number of farms in the department (Table 4). Farmers were selected at random within each municipality. The design of the survey was coordinated by CIAT (Baltensweiler 1992). Results can be considered representative of the population of maize producers in the Department of Jutiapa.

General Characterization of the Jutiapa Department

Jutiapa is located in the southeast of Guatemala and has an area of approximately 322,000 ha. Although there are no official statistics on the total maize area in Jutiapa, a recent study indicated that in 1989 there were 21,579 farmers cultivating 32,170 ha of maize (Viana 1990). They produced about 12% of the maize, 37% of the sorghum, and 39% of the beans grown in Guatemala (Baltensweiler 1992). Use of agricultural inputs is low, which is reflected in the productivity levels of the main crops that have stagnated over the last few years. These crops, however, represent the main source of revenue and nutrients for a typical rural family in the zone (Thornton and Hoogenboom 1990).

Types of soils and rainfall pattern

The soils of Jutiapa are grouped into three classes: (1) the stony and hillside soils of the Central High Plain, which account for 85% of the total area and are only useful as pastures and forests; (2) the fertile, productive, and manageable soils of the Pacific Coast, which cover 5.4% of the total area; and (3) miscellaneous soils, which are generally suitable for agriculture and represent 9.6% of the total area.

The average annual rainfall in Jutiapa is between 1,100 and 1,450 mm/yr, depending on the municipality. However, water availability is a limiting factor for agriculture in the department because rainfall is concentrated during the six-month period from May to October, when 80% of the total annual rainfall occurs (Figure 5),(Simmons, Teramo, and Pinto 1959; Thornton and Hoogenboom 1990).

Table 4. Number and proportion of farms in the population and in the sample, by municipality. Jutiapa, Guatemala, 1991

	Population		Sample	
Municipality	**Farms**	**Proportion**	**Farms**	**Proportion**
Jutiapa	1,844	0.17	33	0.16
El Progreso	401	0.04	6	0.03
Santa Catarina Mita	712	0.07	10	0.05
Agua blanca	839	0.08	14	0.07
Asuncion Mita	1,629	0.15	24	0.12
Yupiltepeque	378	0.04	6	0.03
Atescatempa	711	0.07	10	0.05
Jerez	227	0.02	5	0.02
El Adelanto	177	0.02	3	0.01
Zapotitlan	229	0.02	2	0.01
Comapa	619	0.06	17	0.08
Jalpatagua	431	0.04	3	0.01
Conguaco	659	0.06	19	0.09
Moyuta	863	0.08	33	0.16
Pasaco	78	0.01	2	0.01
San Jose Acatempa	77	0.01	2	0.01
Quezada	598	0.06	13	0.06
Monjas	319	0.03	6	0.03
Total	**10,791**		**208**	

Farm size, land uses, and maize cropping systems

Although the average farm size in Jutiapa is 6.5 ha, statistical analysis reveals an asymmetric distribution (Table 5). A positive skewness value indicates a distribution with an asymmetric tail extending toward more positive values. The larger the skewness value, the greater the asymmetry of the distribution. In Jutiapa, 40% of the farms have less than 2 ha, and 64% have less than 4 ha, further indicating the predominance of small-scale farming in the region (Figure 6).

Sixty percent of the total farm area is devoted to more permanent uses in which pastures, forests, and fallow prevail. Thirty-nine percent of the total farm area is dedicated to the production of grains, mainly maize and beans (Table 6). Most farmers own the land planted to annual crops (61%), while the remaining 39% lease it.[1] There is a positive association between the area allocated to annual crops and land tenure. Landowners cultivate an average of 2.7 ha, while those who rent land cultivate an average of 1.4 ha.

Queried about their land use expectations, most of the farmers (53%) planned to continue sowing the same area, while a sizable group (29%) planned to increase their cultivated area with basic grains and tubers.

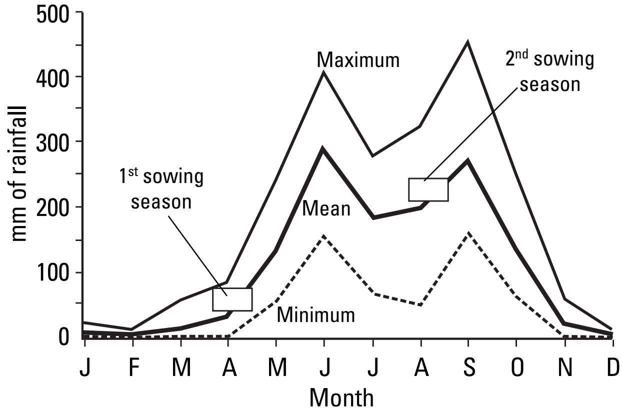

Figure 5. Average, maximum, and minimum monthly rainfall in Jutiapa, Guatemala.

Sources: Simmons, Teramo, and Pinto (1959); Thornton and Hoogenboom (1990).

Table 5. Selected descriptive statistics of farm size and land uses, Jutiapa, 1991

		Area under different land uses (ha)		
	Farm size	**Maize**	**Annual crops**	**Permanent uses**
Mean	6.51	2.38	2.93	3.59
St. Deviation.	12.67	1.63	2.08	12.30
Skewness	6.30	1.83	2.14	6.68
Minimum	0	0	0.04	0
Maximum	131	10	15	128
n	208	207	207	208

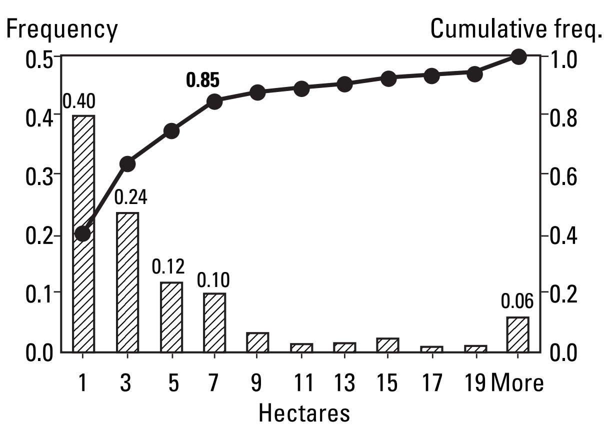

Figure 6. Frequency distribution of farm size in Jutiapa, Guatemala.

Table 6. Land use by small-scale farmers in Jutiapa, Guatemala, 1991

Use	Percentage of the total area
Annual crops	
Grains (mainly maize and bean)	39
Fruits and vegetables	2
Subtotal	**41**
Permanent crops	
Coffee	1
Pastures	33
Forest and fallow	24
Non-productive bushes	1
Subtotal	**59**

[1] Includes 7% of farmers who cropped the land under a share tenancy arrangement. In these cases, costs and profits are shared half and half with the owner.

Maize is sown under two systems: the traditional system, in which maize is associated with other crops, and a monoculture system. In turn, there are three main variations on the traditional system: maize grown in association with beans and sorghum; maize grown only with beans; and maize grown only with sorghum.

The statistical distribution characterizing the area cropped with maize is less skewed than that characterizing farm size (Figure 7). The average area cropped with maize is 2.4 ha, but 82% of the farmers cultivate less than 3 ha. The noted asymmetry of the farm size distribution can be attributed to the skewed distribution of permanent land uses such as forestry and pastures.

There are two seasons for sowing maize in this region, both of which are based on the annual rainfall pattern. The first sowing season starts with the first rains in late April and extends until mid-May. The second sowing season lasts the entire month of August. The second rainfall season is considered riskier in terms of water availability during grain filling. Consequently, the great majority of farmers only plant during the first sowing season; nearly 90% of all the sample farmers planted their maize crop during the first two weeks of May. This approach minimizes the threat posed by erratic rain conditions or drought and also provides farmers with sufficient time to establish a second crop during the second sowing season if they so desire.

Use of Improved Maize Varieties and Hybrids

Types of maize planted by farmers

Almost three-fourths of the farmers of Jutiapa used local maize seed (Criolla) in 1991, while more than one-third used hybrids and improved varieties. Disaggregated data reveals a more complex situation: 46% of the farmers used only local seed; 34% used two or three different types of seed, 19% sowed local and improved seed; and 13% sowed only hybrids (Table 7). Note that only 6% of farmers used *solely* seeds for OPVs, but almost 20% planted OPVs in addition to their local varieties. This was not the case with hybrids, with which little difference was found between the percentage of farmers who planted only hybrids

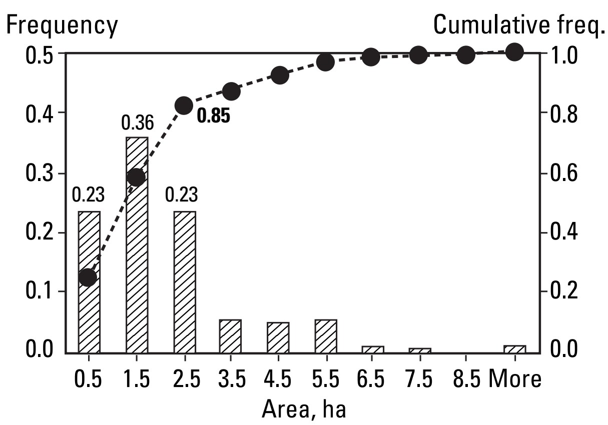

Figure 7. Frequency distribution of the area cropped with maize in Jutiapa, Guatemala.

Table 7. Types of maize seed used by the farmers of Jutiapa Department, first sowing season, 1991

Type of seed used	Farmers	Percentage
Only local	96	46
Only hybrid	27	13
Only improved variety	12	6
Local and hybrid	23	11
Local and improved variety	39	19
Hybrid and improved variety	4	2
Local, hybrid, and improved variety	6	3
Total	**208**	**100**

(13%) and those who planted them as well as local varieties (11%). This difference suggests that the improved varieties are more often sown in addition to the local materials, while the hybrids tend to be sown alone.

Farmers reported using at least 30 local varieties. Eight of these varieties, however, accounted for 85% of the area sown with local materials. The most popular variety, Arriquín, was used by 49% of the farmers. The seven other local varieties, used by 29% of the farmers, are Ulupilse, Bayonil, Americano, Maizón, San Marceño, Cola de Rata, and Candela.

Farmers reported using four improved materials, including two hybrids and two OPVs. Two materials, one OPV (B-1) and one hybrid (H-5), accounted for 80% of the improved materials used by the farmers. An improved OPV (B-5) was used by 11% of the farmers using improved materials and the hybrid HB-83 was reportedly used by 8% of them. It should be noted that in a few instances, the hybrid H-3 was classified as "local."[2]

Looking at land allocation by the type of seed sown, 70% of the study area was cropped with local maize varieties and 30% with improved varieties (17% with hybrids and 13% with OPVs).

Diffusion pattern of improved seed

The diffusion pattern of improved maize seed in Jutiapa was ascertained using a recollection survey among farmers in the sample. Farmers were asked when they had begun buying or exchanging seed of hybrids or improved varieties.[3] To minimize errors frequently associated with this type of data gathering, visual aids were used to construct a timeline based on outstanding events that had occurred in the area during the past two decades. The results partially reflect the impacts of the PROGETTAPS program (Figure 8).

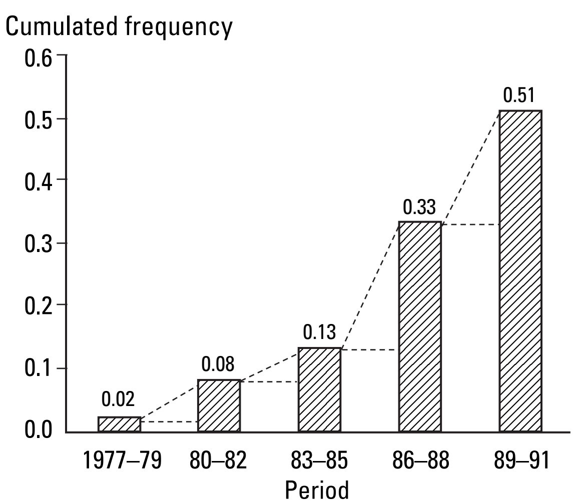

Figure 8. Diffusion pattern of improved maize seed in Jutiapa, Guatemala, 1977–1991.

From 1977 to 1985, the percentage of farmers that used improved varieties increased 11%, while during the following six years (1986–1991) the diffusion of improved seed accelerated, increasing 38% during the period, at an average annual rate that slightly exceeded 6%. Seven percent of the sampled farmers stated that they started collaborating with DIGESA between 1982 and 1985, while 41% started their collaboration between 1986 and 1989.

These results concur with those found in a 1975 study, which showed that during the 1974 cycle almost all the farmers were using

2 H-3 is an old hybrid that originated in El Salvador. Production of H-3 seed ceased several years ago, but it has been recycled by farmers in Guatemala and classified by them as "local."

3 No distinction was made between improved varieties and hybrids; therefore, the diffusion pattern refers to improved materials.

local maize varieties, the most common being Arriquin, Piñuelo, Tusa Morada, and Americano. A strong trend was also found, however, for using two hybrids from El Salvador, H-3 and H-5 (Reiche Caal, Hildebrand, Ruano, and Wyld 1976).

Maize seed acquisition

Three methods of acquiring maize seed were reported by farmers: purchasing seed, storing seed from the previous season, and trading for seed with other farmers. The vast majority of the farmers (75%) acquired their seed using only one form of acquisition, while the remaining 25% acquired seed using either two or three different methods. Storing seed from the previous season was the most frequently reported method of acquisition (66%), followed by purchasing the seed (26%), and trading for the seed (8%).

Farmers who sow hybrid seed have a higher tendency to buy it compared to those who sow improved OPVs (Table 8). This is consistent with the greater productivity losses associated with using advanced generations of recycled hybrid seed.

Within the group of farmers that purchased maize seed, the place of purchase varied with the type of seed (Table 9). In the case of farmers that use local seed, other farmers of the same or other villages are the main sources, while in the case of improved materials—either hybrids or OPVs—stores and other farmers are the principal sources.

When sample farmers were asked which method of acquiring improved seed[4] they liked most, the farmers' voiced a preference toward producing their own seed, either by selection of the best grains or by on-farm production (Table 10). The fundamental difference between these two survey responses is that "on-farm production" implies compliance with the conditions and controls required by PROGETAPPS for a farmer to receive the technical assistance and inputs offered by the project; whereas "selecting the best grains" from the previous crop connotes that the farmer uses traditional seed production methods.

Table 8. Type of improved seed and form of acquisition in Jutiapa, Guatemala, 1991

Seed and form of acquisition	Farmers	Percentage
Hybrid, purchased	26	46
Hybrid, traded or stored	31	54
Improved variety, purchased	21	35
Improved variety, traded or stored	39	65

Table 9. Most common sources of maize seed purchased by farmers in Jutiapa, Guatemala, 1992

	Percentage of farmers	
Source	Local varieties	Improved varieties
Farmer from the same village	80	34
Farmer from other village	20	-
Store in the municipality	-	18
Store outside the municipality	-	18
On-farm seed production	-	6

Table 10. Farmers' preferred forms of acquiring improved maize seed

Forms of acquisition	Percentage of farmers in the sample
Selection of the best grains	37
On-farm seed production	26
Purchase from a store	17
Purchase from another farmer dedicated to on-farm seed production	15
Purchase from a cooperative	5

4 No distinction was made between improved varieties and hybrids; therefore, the preferences regarding the method of acquisition refer to improved materials.

Information on the methods of acquisition and use of improved seed allowed us to estimate that more than 85% of the farmers replace the improved seed (OPVs or hybrids)[5] within three or less cropping cycles and nearly 25% of the farmers replace the seed after only one cycle (Table 11).

One of the conditions that the farmers consider important in determining whether to use improved seed and the number of seasons to use it is its relative profitability. Relative profitability refers to the increase in net returns obtained from using the new improved maize variety instead of the farmer's current variety. An indicator of the relative profitability is given by the marginal rate of return (MRR) defined as (CIMMYT 1988):

Table 11. Number of sowing cycles that the farmers use improved seed

Number of seasons	Percentage of farmers
1	24
2	36
3	26
4 or more	14

$$\textbf{[1]} \qquad \mathbf{MRR} = \frac{\Delta NB}{\Delta VC} = \frac{(\Delta Y * Pm) - (\Delta S * \Delta Ps) * (1+i)}{(\Delta S * \Delta Ps)} = \frac{\Delta Y - (\Delta S * \Delta Pr) \;\; * (1+i)}{(\Delta S * \Delta Pr)}$$

where DNB and DVC represent the incremental net benefits and costs that vary respectively; DY is the increase in maize yield between the improved seed and that which the farmer is using; P_m is the maize price; DS is the increase in the seed rate between both varieties; DP_s represents the price differential; and *i* is the appropriate discount rate encompassing the cost of capital and risk. In the equation it is assumed that the labor cost of sowing both types of seed is the same. Dividing the numerator and denominator of expression [1] by the maize price P_m, the MRR can be stated in terms of the relative seed price P*r* as:

$$\textbf{[2]} \qquad \mathbf{MRR} = \frac{\Delta Y - (\Delta S * \Delta Pr) \;\; * (1+i)}{(\Delta S * \Delta Pr)}$$

According to this equation, the relative profitability of the new improved seed depends on four main factors: (1) the increase in the relative price of the improved seed, (2) the yield gain from the new seed, (3) the increase in the seed rate, and (4) the cost of capital and risk.

Of these four factors, the first two are the most controversial. Historical evidence has shown that widespread diffusion of improved maize seed, particularly hybrid maize, by small-scale farmers has occurred when relative prices are around 5:1 and farmers' yields are modest (< 1.5 t/ha). Under these conditions, adoption is attractive when yield increase is >25% (Heisey, Morris, and Byerlee 1998).

Table 12 shows that relative maize seed prices in Guatemala meet the first condition stated above. The average relative maize price for 1981–1994 was 3.4 and 3.8 for OPVs and hybrid materials, respectively. These prices were for seed sold through the public sector; private sector maize seed prices were 37% higher for hybrids and 18% higher for OPVs (Veliz 1993).

[5] No significant differences were found between hybrids and improved varieties.

The second condition for widespread diffusion refers to the yield gain of improved maize varieties. Some controversy has arisen in the past over the ability of hybrid maize to perform better under low management conditions. There is evidence, however, that the contrary is true. According to Heisey, Morris, and Byerlee (1998): "The most important lesson from successful hybrid adoption stories is that hybrid maize could perform well under relatively unfavorable production conditions and low level of management." Support for this statement is provided mainly by a study in Malawi by Heisey and Smale (1995) and by reports from southern and eastern Africa.

Limited experimental data tends to support the hypothesis that the gains exceed the threshold percentage cited by Heisey, Morris, and Byerlee (1998). The PROGETTAPPS project disseminated two OPVs (ICTA B-1 and ICTA B-5) and two hybrids (HB-83 and HB-85) into the target areas (Cordova, Queme, and Rosado 1992; Veliz 1993). Although farm-level information in this particular case about the yield advantage of these hybrids over OPVs and local varieties is scarce, some useful information is available. Table 13 shows the yield performance of the three most common improved materials used by farmers in Jutiapa. The mean yields of these improved cultivars were estimated from a set of experiments carried out over 11 environments across Central America (Bolaños 1995). The yield gains were estimated over a range of the possible yield values the local varieties would obtain under experimental conditions. The lower limit of 2 t/ha corresponds to the national maize yield average, while the upper limit of 4 t/ha corresponds to the yield level of the hybrid H-5, a historical tester of maize breeding in the region. The *most likely* value of 3 t/ha corresponds to a yield increase of 34% when H-5 is used and a 39% yield

Table 12. Relative prices of maize grain and improved seed, 1981–1994

Year	Grain price[1] (Quetzal/kg)	Improved seed price[2] (Quetzal/kg)		Improved seed/grain price ratio	
		OPV	Hybrid	OPV	Hybrid
1981	0.223	0.674	0.826	3.02	3.71
1982	0.200	0.696	0.870	3.49	4.36
1983	0.223	-	-	-	-
1984	0.193	0.860	-	4.44	-
1985	0.218	1.080	-	4.94	-
1986	0.402	0.870	0.978	2.16	2.44
1987	0.410	1.000	1.330	2.44	3.24
1988	0.383	1.087	1.413	2.83	3.68
1989	0.560	1.304	1.630	2.33	2.91
1990	0.889	1.522	2.174	1.71	2.44
1991	0.867	4.130	4.783	4.77	5.52
1992	0.895	4.348	4.783	4.86	5.35
1993	1.189	4.348	4.783	3.66	4.02
1994	1.308	5.117	5.815	3.91	4.44
Mean	0.569	2.080	2.671	3.428	3.83

Source: 1. Seed unit, ICTA. 2. Bulk market prices. Sección Noticias de Mercado, INDECA.

Note: The exchange rate of the Guatemalan quetzal ranged from 1.01 to the US dollar in 1981 to 2.5 to the US dollar in 1987, and 5.7 to the US dollar in 1994.

Table 13. Yield performance and yield gain of three improved maize genotypes

Name of genotype	Characteristics: Type	Characteristics: Mean Yield (t/ha)	Yield gain for different mean yield of local check (%): Lower	Most likely	Upper	Observations
H-5	White dent hybrid	4.02	101	34	1	Released in 1957
B-1	White dent OPV	4.21	106	39	6	Released in 1970
HB-85	White dent hybrid	5.47	136	69	36	Released in 1985

Source: Mean yield of improved materials is taken from Bolaños (1995).

Note: 1. Calculated using a local white dent variety as a base, with a lower mean yield of 2 t/ha, a most likely yield of 3 t/ha, and a ceiling of 4 t/ha.

increase when B-1 is used. These values concur with "common knowledge"among experts that at the field-level, improved materials increase maize yield by about 35%. Furthermore, experiments carried out in the early 1980s in Guatemala showed that when the average maize yield of local varieties was 1.6 t/ha, improved seed increased yields by about 60% (Cordova 1984, cited by Echeverria 1990).

According to Table 13, the yield gain from adoption of improved materials in Guatemala also exceeds the threshold value of 25% cited by Heisey, Morris, and Byerlee (1998). Limited diffusion must be the result of constraints other than yield gain and/or seed prices. The following section presents an analysis of some of the factors that may be limiting the adoption of improved seed in the region.

The Adoption of Improved Varieties

Conceptual framework

Data on relative prices and yield gains indicate that improved varieties and hybrids are profitable when compared with local varieties. Profitability, however, is only one of the factors that small-scale farmers consider in the process of adoption of new technologies. Other factors include compatibility with the farming system, degree of complexity, divisibility, and the effects of the new technology on the prevailing risk faced by farmers (Byerlee et al. 1980; CIMMYT 1988). Further complicating the picture, the four variables affecting profitability—relative prices, yield gain, seed rate, and cost of capital—have low predictive power in cross-sectional studies of adoption at a regional level at a given time, because most farmers in the region will likely face the same variables (Heisey, Morris, and Byerlee 1998).

The conceptual model used to estimate the demand for improved seed can be illustrated using a scheme in which the farmer must choose between two alternatives: using local seed (j=0) or using improved seed (j=1). The selection of a given type of seed depends on the utility the *i-th* farmer assigns to the characteristics or attributes of the seed (X_{ij}) and on the characteristics (internal and external circumstances) of the household (C_i). That is, each farmer values in different form the characteristics of the alternatives according to his/her internal and external circumstances. The farmer will choose the type of seed that offers him/her the greater utility. The probability that the *i-th* farmer chooses to use the improved seed (alternative 1) can be expressed as the following logistic distribution function (Train 1990; Pindyck and Rubinfeld 1991):

$$\textbf{[3]} \qquad \mathbf{Pi1 = F(Ii)} = \frac{1}{1+e^{-Ii}}$$

where $I_i=Z_i\beta$, is a linear function in the unknown parameters of the seed and farmer characteristics. The function [3] is the base of the logit model used in the empirical part of this work to estimate the adoption probability of improved varieties.

To estimate the probability of partial or total adoption of improved seed, the expression in Equation [3] is normalized in terms of the alternative of no adoption, and the following two logit functions are estimated (Gujarati 1988; Train 1990):

[4] $$L_1 = \ln[\frac{\Pr(Y=1/Zi)}{\Pr(Y=0/Zi)}] = \alpha_{10} + \sum b_{1i} Z_i$$

[5] $$L_2 = \ln[\frac{\Pr(Y=2/Zi)}{\Pr(Y=0/Zi)}] = \alpha_{20} + \sum b_{2i} Z_i$$

Adoption choices available to farmers

When faced with deciding what type of maize to plant, farmers in Jutiapa have three choices: local varieties, OPVs, and hybrid materials. In addition, they also must decide on the seed sources: to use their own seed held from the previous harvest; to buy or to trade for seed from another farmer; to buy or trade from an artisan seed producer associated with PROGETAPP; or to buy it from an agribusiness. Table 14 lists these sources and the types of seed available in Jutiapa. Another characteristic that differentiates the adoption of types of seed material is their origin. OPV's can be acquired from any of the three sources cited in Table 14, while hybrid materials (which were not part of the PROGETTAPP program) were not available from artisan seed producers.

Aside from the type and source of seed (usually referred to as the *quality of adoption*), farmers also determine how much maize area they will allocate to each of the different seed types (*intensity of the adoption*). Figure 9 shows a differentiated pattern of adoption for hybrids and OPVs. About 25% of sampled farmers used OPVs, but most used them on only part of their maize acreage. In the case of hybrids, 24% of farmers used these seed materials and nearly half of that group (44%) used *only* hybrid materials on their maize acreage. Note that due to the small number of observations, the categories for partial and total adoption of both types of improved seed were collapsed into a single category that does not differentiate for intensity.

Table 14. Source and type of seed available in Jutiapa, Guatemala

Source	Type	Most common name
Self and other farmers	Local Old generation OPV and hybrid	Arriquin Old H-5, H-3
Artisan seed producer	OPV	B-1 B-5
ICTA and agribusiness	OPV	B-1 B-5
	Hybrid	H-5 HB-83 HB-85

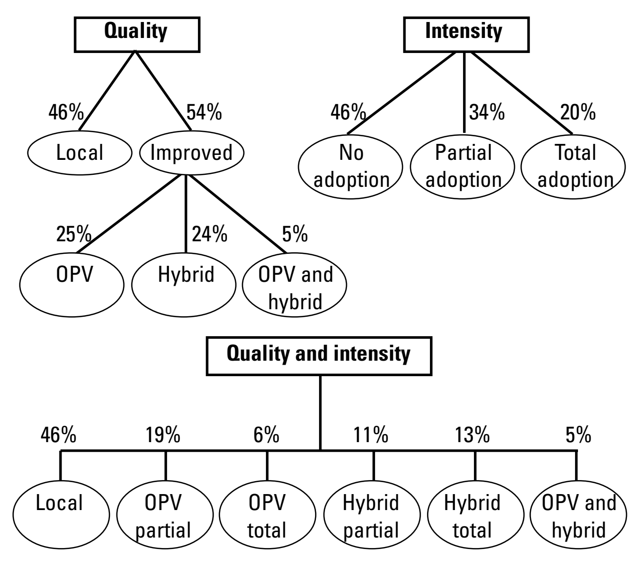

Figure 9. Classification of farmers according to the pattern of adoption in the sample.

This study employed three adoption models to explore farmer adoption patterns. The first model (intensity of adoption) attempts to explain the factors shaping the decision to allocate all or part of the maize acreage to improved seed, disregarding the type of improved seed. The second model (quality of adoption) attempts to identify those factors affecting the choice between types of maize seed, disregarding what percentage of total maize acreage is allocated to each type. The third model considers both choices simultaneously. The definition of the dependent variable and its sample proportion for each model follows.

Model 1. Intensity

In this case, the dependent variable is a qualitative variable that classifies the farmers into one of three categories. The value "1" represents the farmer that has not adopted an improved variety. The value "2" represents the farmer that has partially adopted the improved seed, that is, a farmer who sowed part of the maize area with local seed and part with improved seed. The value "3" represents the full adopter who sows all of his/her maize area with improved materials. Table 15 shows the proportions found in the sample for each category.

Model 2. Quality

In this case, the dependent variable is a qualitative variable that classifies the farmers into four categories. The value "1" represents a farmer that has not adopted an improved variety. The value "2" represents a farmer that has adopted an OPV in part or all of his/her maize area. The value "3" represents a farmer that has adopted a hybrid in part or all of his/her maize area. The value "4" represents a farmer that has adopted both an OPV and a hybrid in part or all of his/her maize area. Table 16 shows the proportions found in the sample for each category.

Model 3. Quality and intensity

In this case, the dependent variable is a qualitative variable that classifies the farmers into six categories. The value "1" represents the farmer that has not adopted an improved variety. The values "2" and "3" represent the farmer that has adopted an OPV on part or all of the area planted with maize, respectively. The values "4" and "5"represent a farmer that has adopted a hybrid in part or all of the area planted with maize, respectively. The value "6" represents a farmer has adopted both an OPV and a hybrid in part or all of the area planted with maize. Table 17 shows the proportions found in the sample for each category.

Table 15. Dependent variable in the model of adoption intensity

Category	Percentage
Non-adopter (Yi =1)	46
Partial adopter (Yi =2)	33
Total adopter (Yi =3)	21
Total (n=186)	100

Table 16. Dependent variable in the model of adoption quality

Categories	Percentage
Non-adopter (Yi =1)	46
Adopter OPV (Yi =2)	24
Adopter Hybrid (Yi =3)	25
Adopter Hybrid and OPV (Yi =4)	5
Total (n=186)	100

Estimation

Independent variables

The independent variables included in the three models are described below, together with their expected effects and main characteristics in the sample. Factors affecting technology adoption generally fall into two main categories: those belonging to the demand side, which are related to farm and farmer's characteristics, and those pertaining to the supply side, which are usually related to technology characteristics and availability (Feder, Just, and Zilberman 1985). This case considers eight variables related to farm and farmers' characteristics and four variables related to the direct and indirect costs of seed acquisition to explain farmers adoption of improved seed.

Farm and farmer's characteristics

System

This is a dummy variable that takes the value "1" if the farmer sows some maize in monoculture, and "0" if all the maize is sown in association with another crop. It is expected that farmers who sow some maize in monoculture will tend to use more improved seed than those that sow maize together with other crops. It is important to remark that the regression analysis implies no causality between the change in the cropping system and variety adoption. It is likely that both changes occur simultaneously as farmers seeking higher productivity and profitability in part or all of their maize area decide to change from local to improved varieties and from the traditional to a monoculture system and vice versa.

Family

This variable looks at the size of the family, measured by the number of persons that live in the farmer's house. It is expected that smaller families will have a higher probability of using improved seed. This hypothesis is based on two arguments. One is that larger families need greater quantities of maize to satisfy domestic consumption, which is preferably accomplished with local maize. The other argument is that larger families use a greater proportion of their total revenue to satisfy vital needs and, therefore, they may have greater budgetary restrictions on the acquisition of improved seed.

Farmsize

The size of the farms was measured in hectares. Numerous studies have included farm size as one of the characteristics most related to the adoption of new technologies. It is also used to characterize the distributive bias of the new technology. It is expected that the larger the farm, the smaller will be the financial and land restrictions for adoption of new technologies, and the greater the probability of adopting improved seed. The relationship between farm size and the probability of adoption was considered non-linear, hence it was introduced into the equation as its natural logarithm.

Table 17. Dependent variable in the model of adoption intensity and quality

Categories	Percentage
Non-adopter (Yi =1)	46
Adopter OPV partial (Yi =2)	18
Adopter OPV total (Yi =3)	6
Adopter Hybrid partial (Yi =4)	12
Adopter Hybrid total (Yi =5)	13
Adopter Hybrid and OPV (Yi =6)	5
Total (n=186)	100

Maizeland

The area sown to maize relative to total farm area. This variable measures the importance of maize in land allocation decisions. The greater the value of the variable (closer to "1"), the greater the importance of maize to the farm. A positive relationship with the probability of adoption is therefore expected.

Ownland

Proportion of land with annual crops owned by the farmer. Land tenure has been an important factor mentioned in the literature on adoption of new technologies, especially in cases related to natural resource conservation and those that require a considerable initial investment. In the case of improved varieties, it is expected to have a positive relationship between land property and the probability of adoption. This positive effect is attributed to a wealth effect. Farmers who own land are richer than those who do not, and it is more probable that the former will adopt the improved variety or hybrid.

Age

Age of the farmer in years. The age of the farm operator is one of the characteristics that is frequently mentioned in the literature as a factor in the adoption of new technologies. Although the results found in previous studies are not conclusive, it is expected that the younger farmers will be more receptive to the new technologies and thus more innovative. The impact of age on the probability of adoption was thought to vary over the relevant range, hence it was introduced into the equation as its natural logarithm.

Education

A dummy variable that takes the value "1" if the farmer has at least one year of school and "0" if he/she does not have formal education. In addition to the farmer's age, the education level is another characteristic that the literature frequently relates to greater rates of adoption of new technologies. A higher educational level has been consistently linked with higher adoption rates. The variable that has been used extensively to reflect education level is years of schooling of the farmer. For the most part, these cases correspond to studies performed in developed countries, where this variable presents a reasonable variability. In this study, however, the formal education of the farmers in the sample was very low. As many as 43% of the farmers had no formal education; 54% had attended an average of two years of primary school; and 3% had attended high school.

Topography

Proportion of the area cultivated with maize that the farmer considers flat. Recent studies (Bellon and Taylor 1993) have shown the importance of farmers' classification of soils on the adoption of new technologies, especially when there is partial adoption. A positive association is expected between this variable and the probability of adoption of improved varieties, because it is more likely that the farmer will invest in flat land with higher probabilities of returns than in hillsides.

Variables related to seed acquisition costs

Distance

This variable represents the distance, in kilometers, from the farm to the nearest municipality where the farmer acquires inputs and sells the farm products. The distance, as well as the time required for the farmer to travel it, are important circumstances that determine the facility with which a farmer can obtain agricultural inputs, sell farm products, and receive technical assistance. As a life circumstance, this factor plays an important role for the farmer in deciding whether to use improved maize materials and other agricultural inputs. The greater the distance, the greater the costs of acquiring the seed and receiving information (technical advice) on its characteristics and management requirements. Therefore, an inverse relationship is expected: Farmers located further from a municipality will have a smaller probability of adopting OPVs and hybrids. The relationship between distance and transaction costs was considered non-linear, thus the variable was included in the equation as its natural logarithm.

Digesa

Number of years the farmer has been collaborating with DIGESA. This variable captures the farmer's degree of information on the program developed by DIGESA about on-farm seed production practices. Therefore, a direct relationship is expected between this variable and the probability of adoption.

Association

Dummy variable that takes the value "1" if the farmer participates in some local organization (association, cooperative, communal committee) and "0" if the farmer does not belong to any organization. In the literature on adoption of new technologies, the affiliation of peasants to regional or local organizations is frequently reported as an important factor related to the adoption of new technologies. It is expected that greater participation in peasant organizations increases the possibilities of obtaining technical assistance services, credit, or other forms of economic assistance, thus reducing the costs of acquiring information and increasing the probability of adoption of improved seed.

Financing

Dummy variable that takes the value "1" if the farmer uses some source of external financing for maize production and "0" if not. This variable is also reported in the literature as an important factor on the adoption decision. It is expected that the access to credit will facilitate the use of inputs purchased outside the farm, such as improved seed. Tables 18 and 19 (p. 18) summarize the description of the variables included in the model and their most important characteristics in the sample.

Results and Discussion

The three models were estimated using the maximum likelihood method.[6] Tables 20, 21, and 22 (pp. 18 and 19) show the results. The models perform well according to the different

[6] Estimation was carried out using the GAUSSX econometric software (Breslaw 1994).

Table 18. Quantitative independent variables, expected effect, and descriptive statistics

Variable	Expected effect	Descriptive statistics of the sample: Mean	Standard deviation	Minimum	Maximum
Distance: Distance from the farm to the closest municipality, in kilometers	-	8.22	7.54	0	36
Age: Age of the farmer, in years	-	44	14.4	17	81
Farmsize: Total farm size, in hectares	+	3.30	2.97	0.5	625
Maizesize: Proportion of total area cropped with maize	+	0.71	0.31	0.02	1
Ownland: Size of the area cropped owned by the farmer, in hectares	+	2.2	2.4	0	15
Digesa: Number of years the farmer has collaborated with DIGESA	+	2.5	3.2	0	26
Family: Number of family members	-	6.0	2.4	1	13
Topography: Percentage of the land sown to maize that the farmer considers flat	+	0.49	0.43	0	1

Table 19. Qualitative independent variables, expected effect, and descriptive statistics

Variable	Expected effect	Sample proportion
System: Takes the value "1" if maize is sown in monoculture	+	0.42
Education: Takes the value "1" if the farmer attended at least one year of school	+	0.42
Association: Takes the value "1" if the farmer participates in at least one communal association	+	0.23
Financing: Takes the value "1" if the farmer used any type of financing in maize production	+	0.16

statistical tests proposed in the literature, with most of the variables having the expected signs. A short discussion of the results follows the presentation of results for both the intensity and quality adoption models. A more thorough analysis is made for the complete model of simultaneous choice of quality and intensity of improved maize adoption.

In the case of the adoption intensity model (Table 20), the results show that there is a differentiated pattern of factors affecting the intensity of improved maize adoption. In the case of partial adoption, three variables (the type of cropping system, the size of the farm, and the relative importance of maize) produced results that significantly differed

Table 20. Factors that affect the intensity of adoption of improved varieties in Jutiapa, Guatemala

Variable	Normalization over non-adoption: Partial adoption	Total adoption
SYSTEM	0.848	0.916
	(2.16)**	(1.99)**
LNDISTANCE	0.014	0.522
	(0.06)	(1.74)*
LNAGE	-0.239	0.476
	(-0.41)	(0.74)
EDUCATION	0.093	0.08
	(0.23)	(0.18)
DIGESA	0.07	0.062
	(1.10)	(0.77)
LOGSIZE	0.893	0.279
	(2.41)***	(-0.69)
OWNLAND	0.164	-0.04
	(1.36) †	(-0.24)
MAIZESIZE	2.25	-0.89
	(2.28)**	(-0.80)
FINANCING	-0.156	0.707
	(0.26)	(1.26)†
FAMILY	0.025	-0.206
	(0.26)	(-2.16)**
TOPOGRAPHY	0.674	0.777
	(1.52) †	(1.54)†
Constant	**-3.602**	**-3.216**

Log-likelihood full model: -165.1 McFadden's pseudo R^2: 0.15
Log-likelihood restricted model: -195.3 n = 186
Percentage correctly predicted: 59 $\chi^2(24)$ = 60.4***
The values in parentheses are asymptotic standard errors.
*** Significant at 1%, two-tails test.
** Significant at 5%, two-tails test.
* Significant at 10%, two-tails test.
† Significant at 10%, one-tail test.

from zero, with the expected signs. In the case of full adoption, the type of cropping system and the size of the family were statistically significant with the expected sign. Besides the aforementioned variables, topography was found significant in a one-tail test in both cases.

In the case of the quality of adoption, the results also show a differentiated pattern of adoption by type of seed (Table 21). In the case of OPVs, topography and experience with DIGESA appear to be the most important factors shaping the adoption of improved varieties, while the type of cropping system seems to have less importance. On the other hand, monocropping maize and farm size are the most important factors for the adoption of hybrids. These factors also appear to influence the simultaneous adoption by farmers' of both OPVs and hybrids.

Results from the estimation of the simultaneous-decision model of quality and intensity show a pattern of effects similar to the individual models (Table 22). Topography and experience with DIGESA seem to be the important factors affecting the choice of OPV materials, while in the case of hybrids, the cropping system and farm size are the most

Table 21. Factors that affect the quality of adoption of improved varieties in Jutiapa, Guatemala

	Normalization over non-adoption		
Variable	**OPV**	**Hybrid**	**Both**
SYSTEM	0.560	1.163	1.293
	1.35†	2.79***	1.65*
LNDISTANCE	0.328	0.05	0.891
	1.02	0.19	1.60
LNAGE	-0.235	0.283	-0.495
	-0.38	0.47	-0.44
EDUCATION	0.175	0.01	0.269
	0.40	0.02	0.32
DIGESA	0.150	-0.087	0.134
	2.05**	-1.0	1.32†
LOGSIZE	0.218	0.861	1.393
	0.55	2.28*	1.91*
OWNLAND	0.174	0.055	0.04
	1.35	0.45	0.22
MAIZESIZE	0.569	0.980	3.050
	0.55	0.97	1.52†
FINANCING	0.631	0.364	-0.587
	1.09	0.62	-0.47
FAMILY	-0.040	-0.100	-0.041
	-0.28	-1.14	-0.28
TOPOGRAPHY	1.02	0.447	0.459
	2.12**	0.95	0.48
Constant	**-2.82**	**-3.58**	**-7.43**

Log-likelihood full model: - 193.9 McFadden's pseudo R^2= 0.13
Log-likelihood restricted model: -221.7 n = 186
Percentage correctly predicted: 54 $\chi^2(36) = 55.6$***
The values in parentheses are asymptotic standard errors.
*** Significant at 1%, two-tails test.
** Significant at 5%, two-tails test.
* Significant at 10%, two-tails test.
† Significant at 10%, one-tail test.

Table 22. Factors that affect the intensity and quality of adoption of improved varieties in Jutiapa, Guatemala

	Normalization over no adoption				
Variable	**OPV partial**	**OPV total**	**Hybrid partial**	**Hybrid total**	**OPV and hybrid**
SYSTEM	0.98	-0.98	0.92	1.24	1.33
	(2.09)**	(-0.99)	(1.65)*	(2.29)**	(1.7)*
LNDISTANCE	-0.02	1.39	-0.02	0.07	0.89
	(-0.06)	(2.08)**	(-0.04)	(0.22)	(1.59)
LNAGE	-0.03	-0.61	-0.58	1.07	-0.58
	(-0.04)	(-0.52)	(-0.69)	(1.40)	(-0.51)
EDUCATION	-0.12	0.42	0.24	-0.23	0.33
	(-0.24)	(0.54)	(0.40)	(-0.43)	(0.38)
LOGSIZE	0.50	-1.27	1.35	0.65	1.47
	(1.09)	(-1.43) †	(2.54)***	(1.46) †	(1.96)*
OWNLAND	0.20	0.36	0.21	-0.30	0.09
	(1.39) †	(1.27) †	(1.45)†	(-1.50)	(0.44)
MAIZESIZE	1.82	-4.14	2.62	-0.38	3.34
	(1.55) †	(-1.72)*	(1.82)*	-0.30	(1.64)*
DIGESA	0.15	0.22	-0.09	-0.07	0.13
	(1.96)**	(1.89)*	-0.80	-0.61	(1.31) †
FINANCING	0.55	0.61	-0.58	0.91	-0.73
	(0.85)	(0.63)	(-0.62)	(1.42) †	(-0.57)
FAMILY	0.01	-0.25	0.06	-0.20	-0.03
	(0.15)	(-1.49) †	(0.50)	(-1.74)*	(-0.19)
TOPOGRAPHY	0.83	1.92	0.37	0.28	0.51
	(1.54) †	(2.02)**	(0.57)	(0.47)	(0.54)
Constant	**-4.52**	**0.17**	**-4.1**	**-4.91**	**-7.53**

Log-likelihood full model: -228.1 McFadden's pseudo R^2= 0.22
Log-likelihood restricted model: -278.9 n = 186
Percentage correctly predicted: 54 $\chi^2(60) = 123$***
The values in parentheses are asymptotic standard errors.
*** Significant at 1%, two-tails test.
** Significant at 5%, two-tails test.
* Significant at 10%, two-tails test.
† Significant at 10%, one-tail test.

important factors. Family size seems to be the main factor discriminating between partial and total adoption of hybrid materials.

The type of cropping system was the only qualitative variable with a significant impact on the probability of adoption. Farmer education was not significantly different from zero at any relevant degree of probability. The possibility of external financing was significant in a one-tail test in the case of total adoption of hybrid materials. Equation [3] was used to estimate the probability of adoption of improved seed for the two cropping systems. These probabilities are calculated for the sample mean values of the quantitative variables and presented in Table 23. The last row of the table presents the impact, in percentage terms, of a change from the traditional to a monoculture system. Results show the importance of the type of cropping system in the adoption decision, particularly in the case of adoption of hybrids.

The impact of the quantitative variables is discussed using their relative impact on the probability of adoption.[7] Table 24 shows the elasticity of the probability of adoption for the quantitative variables whose coefficients were statistically significant. The elasticities were computed for the case of farmers who sow maize in the traditional way.

Table 23. Probabilities of adoption for two types of maize cropping systems

	Probability of adoption				
Cropping system	**OPV partial**	**OPV total**	**Hybrid partial**	**Hybrid total**	**OPV and hybrid**
Traditional	0.15		0.08	0.02	0.02
Monoculture	0.25		0.11	0.05	0.05
Change (%)	**68**		**45**	**119**	**119**

Table 24. Elasticities of the probability of adoption for a typical farmer (percent change in the probability of adoption relative to a 1% increase in the factor)

	OPV		Hybrid	
Variable	**Partial**	**Total**	**Partial**	**Total**
FARMSIZE	-	-1.23	1.25	0.61
FAMILY	-	-1.44	-	-1.14
TOPOGRAPHY	0.36	0.93	-	-
OWNLAND	0.38	0.77	0.43	-
MAIZESIZE	1.07	-2.77	1.67	-
DIGESA	0.32	0.52	-	-

Farm and farmer characteristics

Farm size

The size of a farm has a positive impact on the probability of adoption of hybrid seed, particularly in the case of partial adoption. An increase of 10% in the total farm area results in an increase of approximately 12.5% in the probability of sowing part of the maize acreage with hybrid maize. The size of the farm and its ownership are two characteristics that positively affect the probability of adoption of improved seed. A larger farm area is indicative of greater wealth and income, which, in turn, are highly related to the possibility of acquiring more and better agricultural inputs. These results are consistent with those found in other studies on adoption of new technologies (Brush, Taylor, and Bellon 1990; Belknap and Saupe 1988; Rahm and Huffman 1984).

[7] The elasticity e_i measures the change in the probability of adoption relative to a change in the factor. It is calculated as: $e_i = b_i * X_i * (1- P)$; where bi represents the estimated coefficient associated to the i-th variable and P the probability of adoption (Train 1990).

Land tenure

The size of the area under annual crops owned by the farmer also has a less than proportional positive impact on the adoption of OPVs. An increase of 10% in the area under annual crops owned by the farmer brings about an increase of 4–8% in the probability of adoption of OPVs in part or in the entire area cropped with maize. This result is congruent with expectations and with previous findings (Brush, Taylor, and Bellon 1990; Belknap and Saupe 1988).

Importance of area with maize

The proportion of total farm size cropped with maize seems to have an important role in the adoption decision process in the household, particularly when the choice refers to the intensity of the process. A 10% increase in the relative size of the area sown with maize brings about an 11% increase in the probability of partial adoption of OPVs and an 18% increase in the probability of partial adoption of hybrid materials. When considering the option of total adoption of both types of seed, the direction is the opposite. In the case of OPVs, a 10% increase in the variable brings about a strong 28% decrease in the probability of total adoption in the entire area cropped with maize.

Family size

As expected, the size of a family has an important influence on the total adoption of hybrids and OPVs. The elasticity coefficients show that a 10% increase in the family size reduces the probability of total adoption of OPVs by 14% and that of hybrid materials by 11%. This result is consistent with the hypothesis on the importance of local maize in domestic consumption. In the case of partial adoption of either OPVs or hybrids, the number of family members is not important. Similar results were found in the works of Brush, Taylor, and Bellon (1990), and Rauniyar and Goode (1990).

Topography of maize plot

The topography of the maize plot has, as expected, a positive impact on the probability of adoption of OPVs and hybrid materials. However, the coefficients were significant only in the case of OPVs. An increase of 10% in the proportion of the maize plot considered by the farmer as flat, increases the probability of OPV adoption by 4% and 9% in cases of partial and total adoption, respectively. This result is consistent with that reported by Bellon and Taylor (1993), who found a clear association between soil quality and adoption of improved maize varieties in Chiapas, Mexico.

Experience with DIGESA

As expected, the number of years that a farmer has been involved in the DIGESA program has a significant positive impact on the probability of adoption of OPVs, but it is irrelevant for hybrid materials. A 10% increase in number of years with the program increases the probability of adoption of OPVs by 4% and 5% in the cases of partial and total adoption, respectively. The program did not push farmers to adopt the new improved varieties in their entire maize area. As a result, this variable has no impact on adoption intensity.

To summarize, the factors identified as affecting the adoption of improved seed are indicative of a two-step process. Partial adoption decisions seem to be based mainly on factors such as family size and the relative importance of maize on the farm. Quality of adoption is mainly regulated by factors such as farm size, which favor adoption of hybrid seed, while land tenure and topography favor adoption of OPVs. In addition to these considerations, the results support the view that adoption of OPVs and hybrids, either partial or total, coincides with changes in the way maize is cropped—from traditional cropping in association with sorghum and beans to monoculture.

These findings concur with the conclusions reached by Smale, Just, and Leathers (1994) that land allocation decisions between traditional and new varieties are regulated by the simultaneous effects of several of four factors: input fixity, portfolio selection, safety-first behavior, and farmer experimentation and learning.

Other factors often mentioned in the literature as influencing the adoption of new technology, such as distance from the market, the level of farmer's education, and farmer's age were not found significant in the proposed model. The coefficients related to the external source of financing display the expected sign, but were not significantly different from zero, the only exception being the association with full adoption of hybrid seed that showed significance at 10% in a one-tail test.

Summary and Conclusions

The majority of the maize producers of Guatemala are small-scale subsistence farmers that generally do not have access to agricultural inputs such as improved varieties and hybrids. The Project for Generation and Transfer of Agricultural Technology and Seed Production (PROGETTAPS) was launched in 1986 with the aim of improving the access of small-scale farmers to improved seed.

This paper identified the intensity of use, forms of use, diffusion pattern of improved seed, and factors that influence the quality and intensity of its adoption by small-scale farmers in the department of Jutiapa, Guatemala. The paper also addressed the issue of the impact of PROGETTAPS, an ICTA/DIGESA program, as a means to diffuse improved seed among small-scale farmers in the country.

Study findings revealed a complex pattern of seed use in Jutiapa. Although the farmers there use several types of local and improved maize seed, they seem to prefer and use the local variety known as Arriquin, as well as two improved materials, an open-pollinated variety (B-1) and a hybrid (H-5). The reported forms of acquisition and preferences indicate that most of the farmers use the same material for 1–3 sowing seasons. Yield gains and relative prices, two important factors determining the profitability of adoption of new varieties, are adequate. By changing from their local varieties to OPVs and hybrids, farmers most likely can expect yield increases ranging from 35% to 70%. These gains may be obtained by paying prices that are equivalent to 3–4 kg of local maize seed for 1 kg of improved OPV or hybrid seed.

The decision to use improved materials in part or all of the area cropped with maize is associated with a change in the maize cropping system. Results suggest that farmers who sow a plot of maize in monoculture tend to plant the entire area with improved seed, particularly with hybrids. This is consistent with the hypothesis that farmers who plant maize in monoculture reserve their product primarily for the market. Therefore, the productivity of the land is a key component of the decision on what variety to use, while consumption preferences play a secondary role. This hypothesis is supported by the findings on the effects of family size. Results show that the size of the family, taken together with the cropping system, is an important factor influencing the probability of full adoption, particularly of hybrid materials.

The results also show that the probability of using hybrid materials, either in part or all of a cropped area, increases with the farm size. This has important implications for extension services and policymakers, who should consider these factors when establishing their priorities and future extension strategies.

Importantly, results from the estimating model confirmed the trend observed at the aggregated level. PROGETTAPS had a significant impact on the adoption of OPVs in Jutiapa. Farmers with experience with PROGETTAPS are more likely to adopt OPVs than those who do not have contact with it. Furthermore, the probability of adoption increases with the years of association farmers have with the program.

Another factor that seems to play a role in determining full adoption of improved varieties and hybrids is the farmer classification of the topography of the maize plot. This indicates that farmers allocate land to improved seed according to their perception of land quality.

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